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# THE LARVAL STAGES OF *RANINA RANINA* (LINNAEUS) (CRUSTACEA, DECAPODA, RANINIDAE) REARED IN THE LABORATORY, WITH A REVIEW OF UNCERTAIN ZOEAL LARVAE ATTRIBUTED TO *RANINA*

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*With 17 Text-figures*

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## I. Introduction

The larval development in the family Raninidae has been recently described on two species, firstly in six zoeal stages and megalopa of *Lyreidus tridentatus* DE HAAN from New South Wales, Australia (WILLIAMSON, 1965), and secondly in four zoeal stages and megalopa of *Raninoides benedicti* RATHBUN from Cape Corrientes, the Pacific coast of Mexico (KNIGHT, 1968). WILLIAMSON (1965) summarized the larval characters of the Raninidae, but yet the knowledge of the larvae of *Ranina ranina* does not surpass the limits of the stage I zoea described by AIKAWA (1941) and RICE (1970).

The author succeeded in 1970 in rearing zoeae of *R. ranina* obtained from laboratory hatching for eight stages at the Usa Marine Biological Laboratory of the University of Kochi, Japan, and their morphologies are described here in detail. The uncertain larvae, closely related with those of *R. ranina*, from the West Indies (WESTWOOD, 1835), from Bermuda (GURNEY, 1942, LEBOUR, 1950, 1959), from Bengal (CLAUS, 1876, 1885) and from Japan (AIKAWA, 1933) were reviewed.

The author is much indebted to Dr. K. YATSUZUKA of the University of Kochi for teaching the author his technics of rearing larvae in the laboratory.

## II. Material and Methods

On July 27 1970, ten ovigerous females caught off the coast of Susaki, Kochi prefecture of Shikoku Is., facing the Pacific by the scoop net were bought at the Susaki Fishing Market and carried alive by car, being burried in dry sand, to the laboratory in an hour, and then released in the concrete pool filled with the sea-water of the chlorinity higher than 15 ‰.

The first release of zoeae occurred just after the ovigerous females were returned in the sea-water on July 27, the second on July 30 and the third on August 5. The larvae thus obtained were reared in the sea-water not circulating (SAKAI, 1971). About seventy to eighty larvae were reared in each of four glass bowls, respectively containing 3 l of sea-water, of which the temperature was 28-29°C at the maximum and the chlorinity was regulated in the range 16-17 ‰. Newly hatched nauplii of *Artemia* were prepared as food for larvae.

One of the ovigerous females (75 mm in carapace length) purchased at the market and deposited in the author's collection was found bearing more than 30,000 eggs. The larvae obtained in the laboratory are preserved in ethyl alcohol and kept in the author's collection. Of these, a series of the zoeal larvae are to be presented to the British Museum, and Smithsonian Institution in Washington, D. C.

### III. Results

None of the larvae reached the megalopa stage, but eight attained to the stage VIII zoea, presumably the last stage, and other ten died during the seventh molt. The first and second molts occurred regularly with peaks in 4-5 and 5-6 days after hatchings respectively. The molt after the third occurred continuously but with an indistinct peak every 4-5 days. The mortality increased after the third molt, especially in the sixth and seventh stages. Numbers of molted larvae in respective zoeal stages may be roughly counted in table 1.

Table 1. Measurements of cultured larvae of *Ranina ranina*.

Stage	Carapace leng. mm	Rostrum leng. mm	Tip of rostrum to tip of dorsal spine mm	Lateral spine leng. mm	Tip of eye to posteromedial margin of telson mm	No. of larvae in 4 bowls
I	1.1	3.3-3.4	6.6-7.3	0.5	2.6-2.8	280
II	1.3-1.4	5.0-5.6	9.8-10.5	0.4-0.5	3.1-3.2	268
III	1.7-2.0	7.1-8.0	14.0-15.0	0.3-0.4	3.9-4.3	191
IV	2.3-2.6	9.2-10.4	17.3-20.0	0.3-0.4	4.8-5.6	140
V	2.8-3.0	10.3-11.3	20.5-23.3	0.3	6.2-6.3	68
VI	3.3-3.5	12.7-13.4	21.2-24.0	0.3	6.7-6.8	54
VII	4.0-4.4	13.5-13.7	—	0.3	8.0-9.3	49
VIII	5.0-5.8	15.0	—	0.3	12.2	18

### IV. Morphology

*Ranina ranina* (LINNAEUS): stage I zoea, AIKAWA, 1941; stage I zoea, RICE, 1970.

The following is the description of the zoeal larvae of *R. ranina* obtained by laboratory hatching and rearing. Illustrations are given in detail, but generally

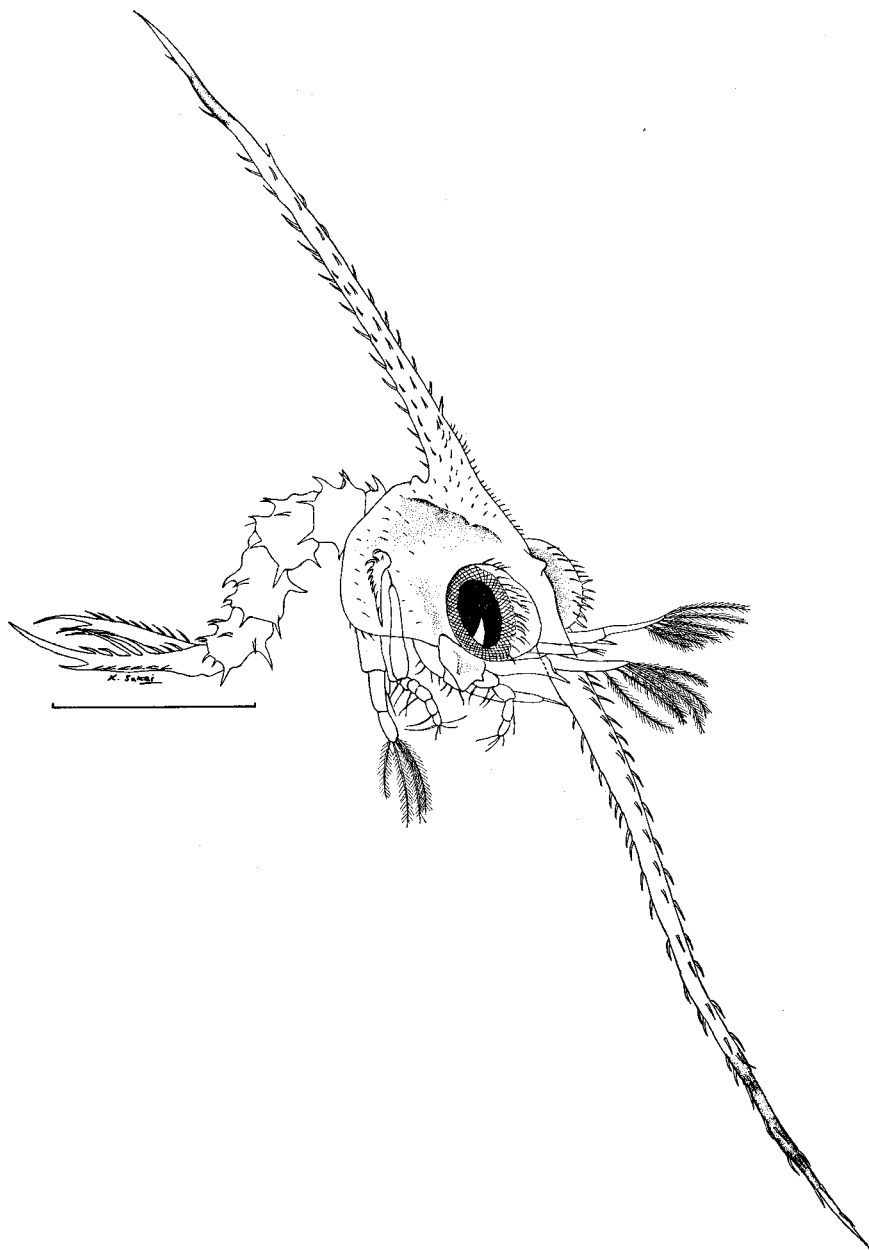


Fig. 1. Stage I zoea of *Ranina ranina* (LINNAEUS). Scale line for 1 mm.

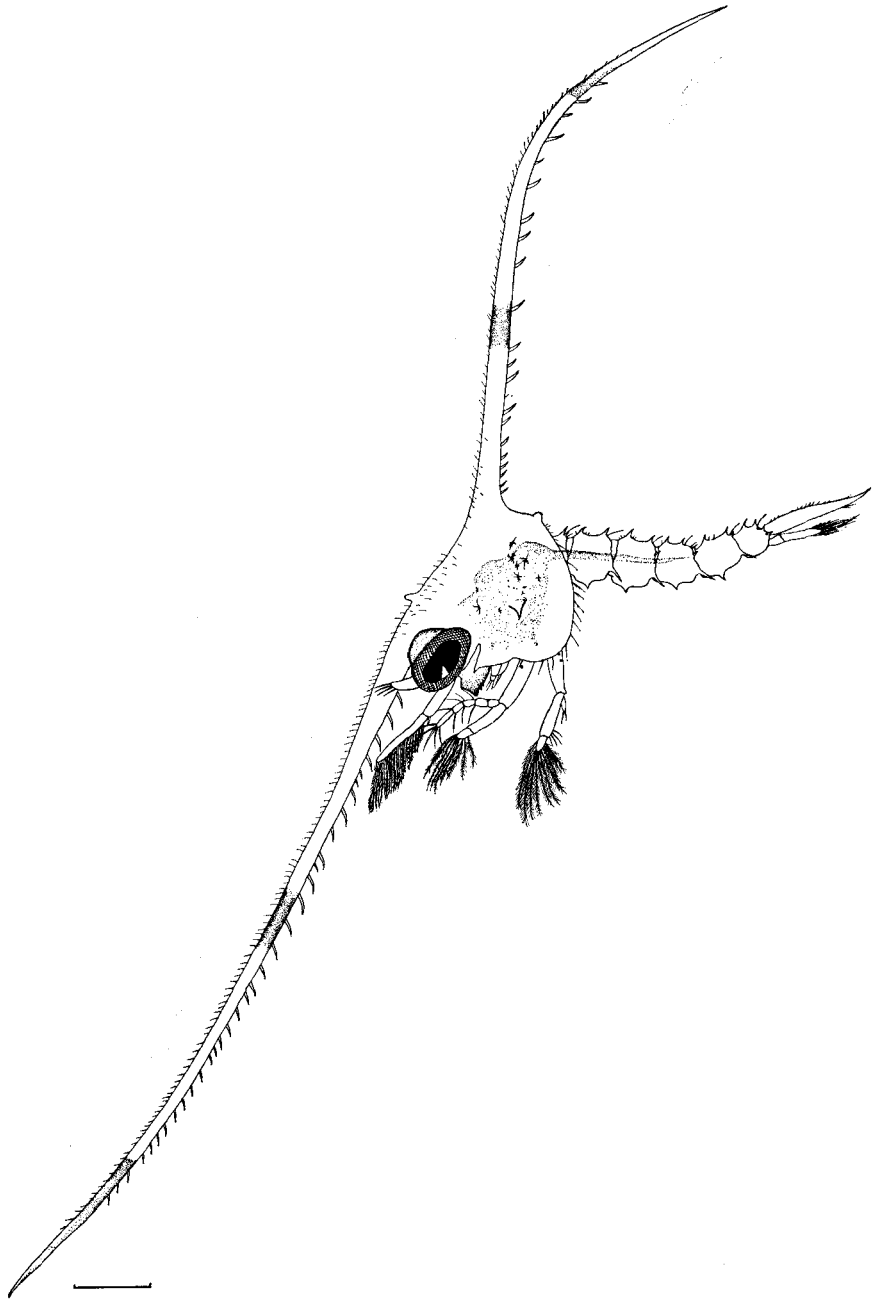


Fig. 2. Stage IV zoea of *Ranina ranina* (LINNAEUS). Scale line for 1 mm.



Fig 3. Stage VIII zoea of *Ranina ranina* (LINNAEUS). Scale line for 1 mm.

restricted to the major changes in morphology from stage to stage. Measurements in respective zoeal stages are given in table 1. The length of the carapace was always measured from the anterior margin of the eye to the posterior margin of the carapace.

*Colour* The stage I–III zoeae bear a reddish stripe on each of the rostral and dorsal spines of the carapace. The stage IV zoea is marked with two reddish stripes on each spine. The stripes on the rostrum increased in number in later stages (Figs. 1–3).

#### Zoea I

The carapace is bristly with spinules. The rostrum is long and spinulous. It faintly curves ventrally near the middle part, but returns anteriorly slightly near the tip. The dorsal carapace spine faintly curves posteriorly near the distal part and

with a distinct row of spinules along the lower margin in addition to a few rather irregular rows of a little smaller spinules on other sides. The lateral carapace spines (Fig. 4a) are each slender in appearance and provided with a series of small elongated spearheaded spines on the dorsal margin, while the ventral margin being smooth. The anterior and posterior dorsal tubercles are clearly represented on the median line of the carapace.

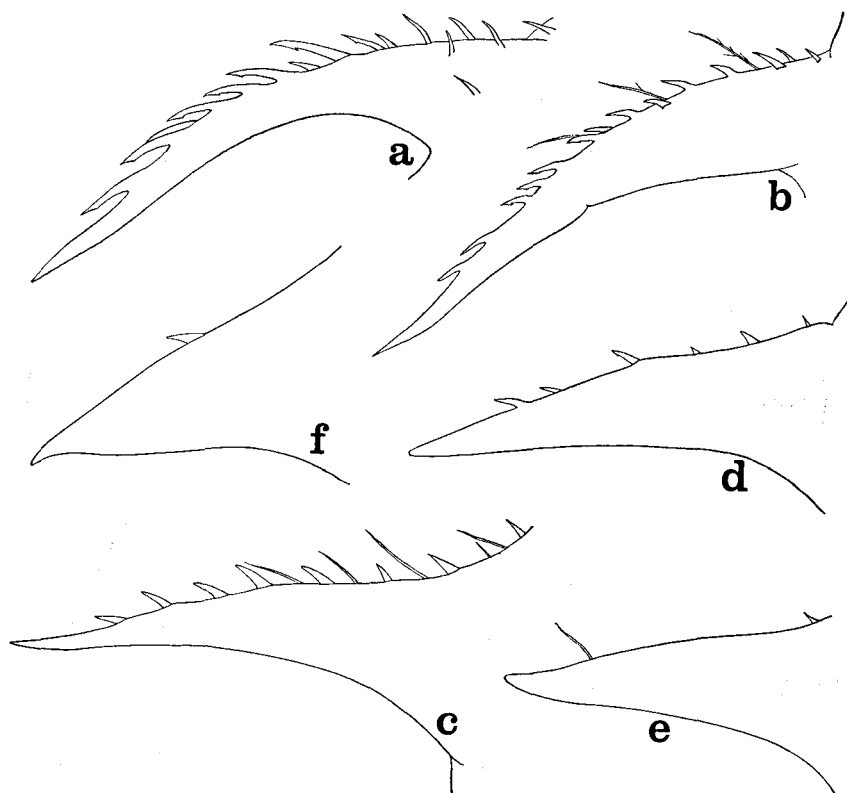


Fig. 4. Lateral carapace spines of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage III zoea, d: in stage IV zoea, e: in stage VI zoea, f: in stage VIII zoea.

The eyes are sessile. The eye-stalk is distally provided with some spinules along the cornea, which are prominent anteriorly, and bears a small papilla at the middle part of the anterior margin.

The first antenna (Fig. 5a) is a short rod furnished with three aesthetascs and two short setae at the tip.

In the second antenna (Fig. 6a) the endopod is represented by a small spine furnished with a long plumose terminal seta. Close to the endopod, the proximal segment issues a small ventral spine on the distal margin, which is much longer than

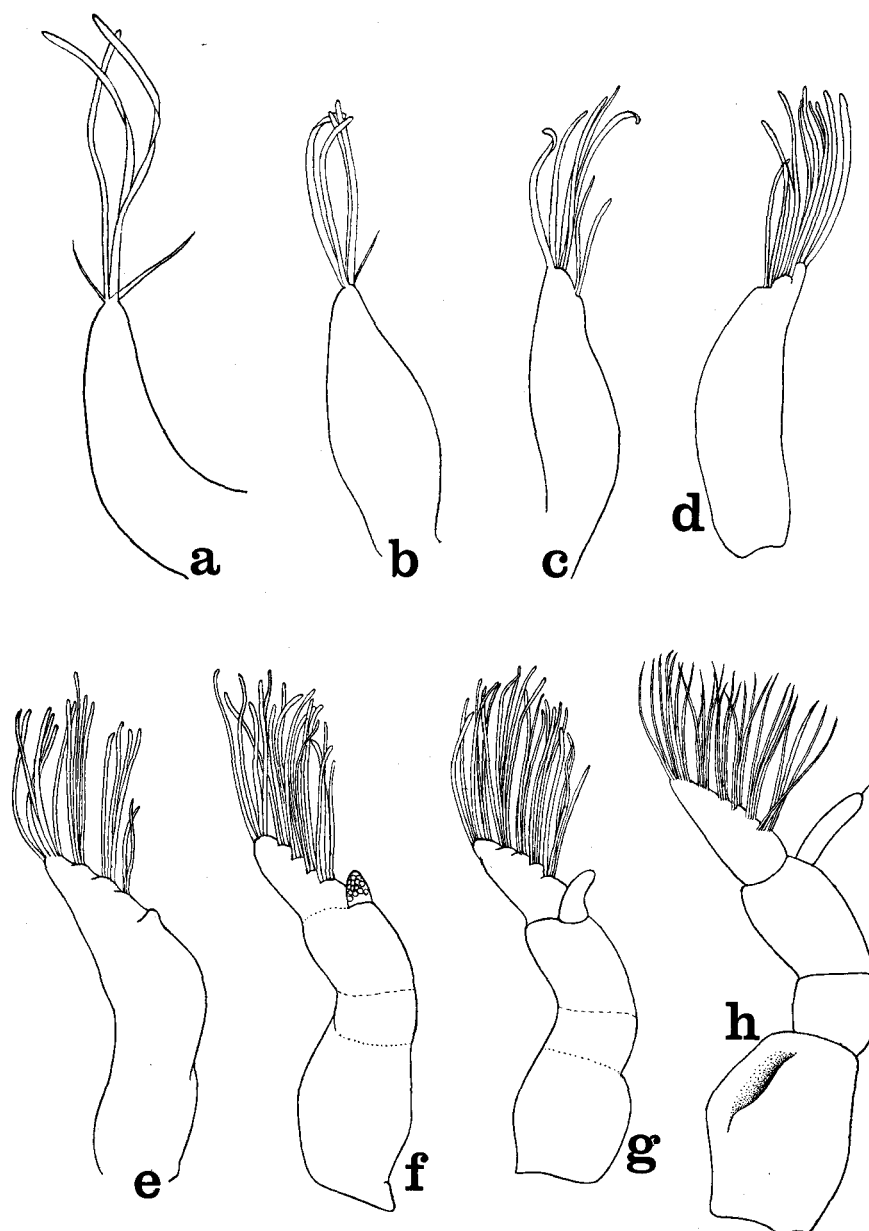


Fig. 5. First antennae of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage III zoea, d: in stage IV zoea, e: in stage V zoea, f: in stage VI zoea, g: in stage VII zoea, h: in stage VIII zoea.



the endopod and serrated around its margin. The exopod is elongate and flattened like a scale and fringed distally with six plumose marginal setae.

The mandible bears no palp. The incisor process is provided with the cutting edge rectangularly curved at a strong tooth and then being divided into the dorsal and frontal edges, the former is slightly curved and ends in a small tooth, while the

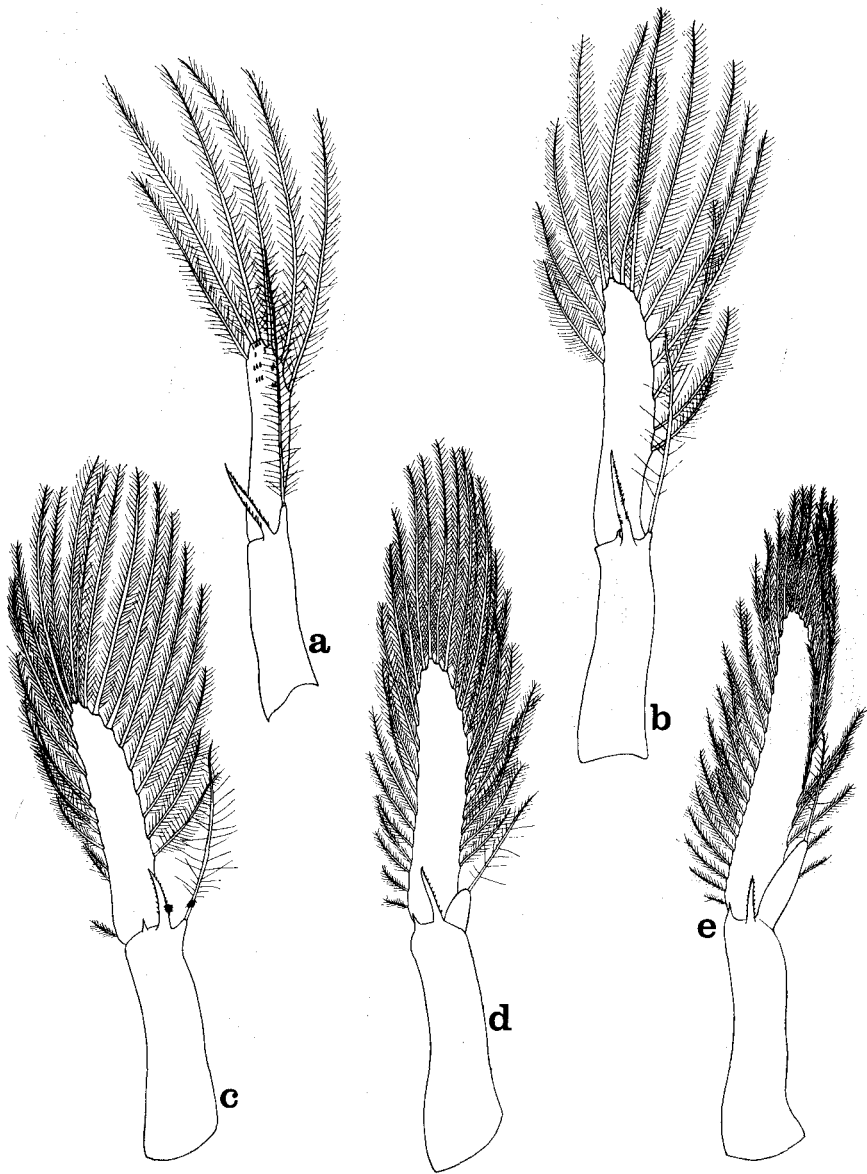


Fig. 6. Second antennae of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage III zoea, d: in stage IV zoea, e: in stage V zoea.

latter is broadly concaved and armed with 3-4 rather indistinct denticles spaced one another.

In the first maxilla (Fig. 8a) the proximal endite is provided with six marginal setae. The distal endite bears four strong setae on the distal margin, in addition two other distal setae on the outer surface and another one on the inner surface near the margin. The palp is two-segmented, the distal segment bearing four long terminal setae and one subterminal one on the inner margin.

In the second maxilla (Fig. 9a) the first or proximal, second, third and fourth or distal endites are respectively armed with 3 : 3 : 5 : 4 setae, the last two bearing additionally a small subterminal seta respectively. The palp is furnished with three terminal setae and two setae on an inner lobe. The scaphognathite is fringed with five plumose marginal setae and with a strong apical seta on the posterior end.

In the first maxilliped (Fig. 10a) the coxa bears a plumose seta on the inner margin. The inner margin of the basis is armed with a row of 2 : 2 : 2 : 3 setae from proximal to distal. The endopod consists of five segments, the ischium to the propodus bear respectively 3 : 2 : 1 : 2 setae. The dactylus bears four terminal setae and one subterminal seta on the outer margin. The exopod is vaguely two-segmented and furnished with four plumose natatory setae.

In the second maxilliped (Fig. 12a) the coxa bears no seta. The basis bears on the inner margin four setae spaced one another. The endopod is three-segmented, the first or proximal segment and the second bear each a single seta distally on the inner margin. The third or distal segment is provided with three terminal setae; the inner seta is long and spinouse, the middle short and nearly simple and the outer long and plumose. The exopod shows the same form and setation with that of the first maxilliped.

The third maxilliped and the pereopods I-V are undifferentiated, though there are faint, transverse comb-like sutures just behind the second maxillipeds.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	-	-	-	-	-	-	-	-
Arthrobranchs	-	-	1	-	-	-	-	-
Podobranchs	-	-	-	-	-	-	-	-
Epipods	1	1	-	-	-	-	-	-
Exopods	1	1	-	-	-	-	-	-

The abdomen (Fig. 13a) is five-segmented. The first segment bears on the posterior margin two pairs of dorsolateral spines and a dorsal spine on the median line. The second segment is armed with a pair of spiniform lateral papillae, and slightly posterior to it there is a small spine. The posterior margin of the second

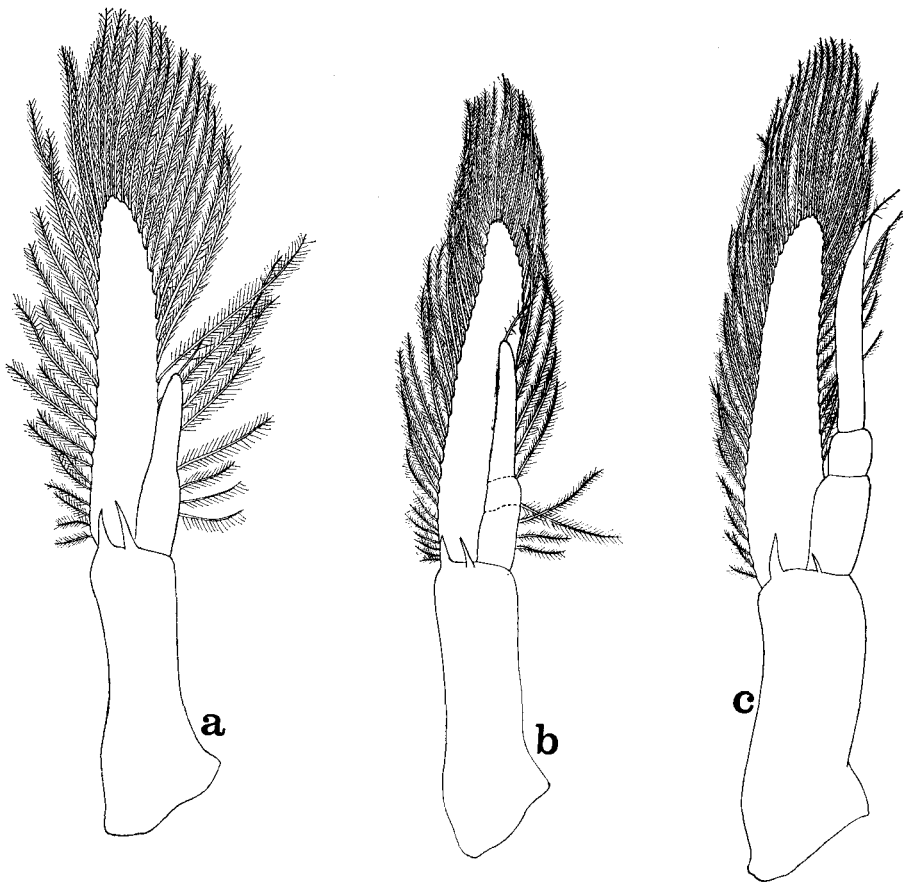


Fig. 7. Second antennae of *Ranina ranina*, a: in stage VI zoea, b: in stage VII zoea, c: in stage VIII zoea.

segment is provided with a dorsal spine and a pair of the dorsolateral and ventrolateral spines. The middle part of this segment presents two dorsal spines juxtaposed one another and a ventral spine on the median line. The third to fifth abdominal segments present on the posterior margin the same setation as in the second segment but with an additional pair of dorsal spines on the middle part. The first to fifth abdominal segments are on the posterior margin furnished with a pair of smooth hairs just beside the dorsal spine.

The telson (Fig. 14a) is somewhat like a fork with paired narrow arms opened apparently wider than the right angle. Each arm bears usually six smooth anterolateral spines, three posteromedial setae, plumed and setose, and three posterior spines. The outer spine on the posterior margin is simple, but the middle and inner spines are each plumed. The dorsal surface is provided with 8–10 spinules along the

posteromedial margin, the outer most ones of which are a little larger than others and lying respectively on the proximal part of the inner one of the three posterior spines.

## Zoea II

The rostrum is spinous. The spinules on the lower margin are arranged in a distinctive row. The dorsal surface of the carapace is divided by a longitudinal keel into two regions, each well protruded and scattered with some prominent bristles. The posterior margin of the carapace is fringed with a few long plumose setae.

The eyes are movable. The eye-stalk is sparsely setose, the setae are less distinctive than in the stage I zoea.

In the first antenna (Fig. 5b) the rod carries four long aesthetascs and at least two short setae set in a tier at the tip.

The second antenna (Fig. 6b) bears a small incipient ventral spine just outside the serrated spine on the proximal segment. The plumose terminal seta of the endopod is much shortened not to reach the end of the exopod. The exopod is armed with 14–17 plumose marginal setae.

In the mandible the frontal edge of the incisor process is armed with an asymmetrical row of denticles, and the dorsal edge presents an indistinct tubercle near the distal tooth.

In the first maxilla (Fig. 8b) the proximal endite bears eight marginal setae. The distal endite is armed with five strong marginal setae and two setae respectively on the outer and inner surfaces along the margin and with one on the proximal margin. There is a plumose seta on the outer margin of the segment. The palp bears four terminal setae and one subterminal seta on the inner margin.

In the second maxilla (Fig. 9b) the first, second, third and fourth endites are respectively armed with 4 : 3 : 5 or rarely 6 : 6 or rarely 5 marginal setae. The palp bears three terminal setae at the end and two on the inner lobe, and in addition a seta on the outer margin. The scaphognathite has usually sixteen plumose marginal setae including on the posterior margin five setae which are remarkably stout at the foot.

In the first maxilliped (Fig. 10b) the setation on the inner margin of the basis is 2 : 2 : 3 : 3 from proximal to distal. The ischium, merus, carpus and propodus bear respectively 3 : 2 : 1 : 3 setae on the inner margin, and 0 : 0 : 1 : 1 on the outer margin. The dactylus bears six terminal setae and one seta on the outer margin. The distal segment of the exopod is fringed with 10–11 natatory setae.

In the second maxilliped the coxa bears a small seta on the inner margin. The exopod bears 11–13 natatory setae on the distal segment.

The third maxilliped and the first pereopod appear respectively as a small bud. The second to fifth pereopods form respectively a comb-like plate.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	—	—	—	—	—	—	—	—
Arthrobranchs	—	—	1	1	1	—	—	—
Podobranchs	—	—	—	—	—	—	—	—
Endopods	1	1	r	r	r	r	r	r
Exopods	1	1	—	—	—	—	—	—

(r = rudiment)

The anterolateral spines of the telson are diminished in size. Each arm bears six posteromedial setae, strong, plumed and setose, besides 1–2 slender and plumed setae situated further inside (Fig. 14b).

### Zoea III

The carapace bears some additional plumose setae on the posterior and lateral margins. The lateral carapace spines are much broadened (Fig. 4c).

In the first antenna (Fig. 5c) the rod bears a terminal tier of five aesthetascs and another subterminal tier of two aesthetascs on the medial margin.

In the second antenna (Fig. 6c) the exopod is furnished with 22–26 plumose marginal setae.

In the first maxilla the proximal endite bears 9–12, often 10–11 marginal setae. The distal endite bears seven strong setae on the distal margin, 3–4, usually 4 setae on the outer surface along the margin, 3 on the inner surface and 2–3, often 3 on the proximal margin. The palp bears five terminal setae and one subterminal seta on the inner margin.

In the second maxilla the first, second, third and fourth endites bear respectively 5–6, rarely 7 : 4 : 6–8 : 7–10, frequently 7–8, marginal setae. The palp is unchanged in setation. The scaphognathite bears 22–28, usually 23–27 marginal setae.

In the first maxilliped (Fig. 10c) the coxa bears two setae on the inner margin. The basis bears sparsely seventeen setae on the inner margin. In the endopod the ischium to the propodus are each armed with 3, rarely 4 : 2 : 3 : 4–5 setae on the inner margin, and with 0 : 0 : 2 : 2 setae on the outer. The dactylus bears 7–8 terminal setae and two setae on the outer margin. In the exopod the proximal segment bears distally one seta on the outer margin, which continues to a row of setae on the outer margin of the distal segment which is further furnished with 15–17 natatory setae.

In the second maxilliped the proximal segment of the exopod bears 1–2 setae, and the distal segment bears 16–18 natatory setae.

The first pereopod is represented as a swollen rod larger than the third maxilliped. The second to fifth pereopods are still in the state of a rudimentary rod.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	—	—	—	—	1	1	1	—
Arthrobranchs	—	—	r+1	r+1	r+1	r	—	—
Podobranchs	r	—	—	—	—	—	—	—
Endopods	1	1	r	r	r	r	r	r
Exopods	1	1	—	—	—	—	—	—

(r = rudiment)

The abdominal segment has the ventrolateral spine beset with a small spine at the upper foot. The sixth abdominal segment is demarcated from the telson and armed with a pair of small ventrolateral spines on the posterior margin, further with a minute dorsolateral spine slightly above the ventrolateral spine on each side (Fig. 13b).

The telson (Fig. 14c) bears on the posteromedial margin 8–9 strong and 3–5 slender setae. The inner spine on the posterior margin is less attenuated. The exopod of the uropod (Fig. 16a) bears eight plumose marginal setae.

#### Zoea IV

The median papilla of the eye-stalk is positioned near the foot of the cornea.

The first antenna (Fig. 5d) bears on the medial margin a terminal tier of five aesthetascs, subterminal one of four aesthetascs, and another more proximal tier of two aesthetascs.

In the second antenna (Fig. 6d) the endopod is distinctively enlarged, the terminal seta becomes much shorter, only reaching about the middle of the exopod. The exopod is fringed with 29–33 plumose marginal setae.

In the first maxilla the proximal endite bears 13–16 marginal setae. The distal endite bears seven strong marginal setae, 4–5 setae on the outer surface, four on the inner surface and 3–4, usually 3 setae on the proximal margin. The palp bears five terminal setae and one seta respectively on the inner and outer margins.

In the second maxilla the first, second, third and fourth endites are respectively armed with 7–10, usually 7–8 : 4–5 : 7–8, rarely 6 or 10 : 8–10, often including smaller 1–2, setae. The palp bears three terminal setae, two setae on the inner margin which bears no lobe that is remarkable in the preceding zoeal stages I–III, and two setae on the outer margin, which are both rather slender and the distal one appears near the tip. The scaphognathite bears 36–39, rarely 35 or 41 marginal setae.

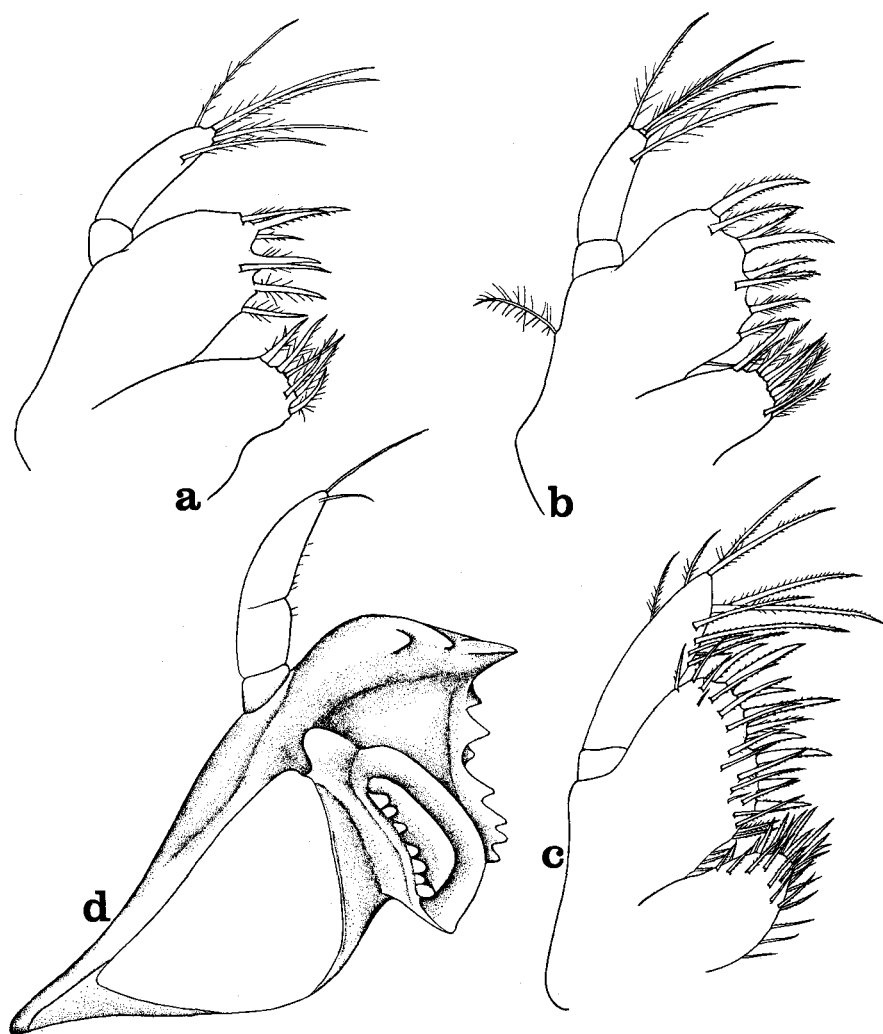


Fig. 8. Mandible and first maxillae of *Ranina ranina*, a: first maxilla in stage I zoea, b: the same in stage II zoea, c: the same in stage VIII zoea, d: mandible in stage VIII zoea.

In the first maxilliped (Fig. 11a) the coxa is armed on the inner margin with three setae and rarely another small seta. The basis bears sparsely 19–23 setae on the inner margin. The ischium to the dactylus bear respectively 4 : 2–3 : 3 : 5 setae on the inner margin and 0 : 0 : 2, rarely 3 : 3 setae on the outer margin. The number of setae on the dactylus has increased, they are 8–10, usually 9 on the distal margin and three on the outer margin. In the exopod the proximal segment bears three setae distally on the outer margin and the distal segment bears 18–23 natatory stae.

In the second maxilliped the endopod remains unchanged in setation from that

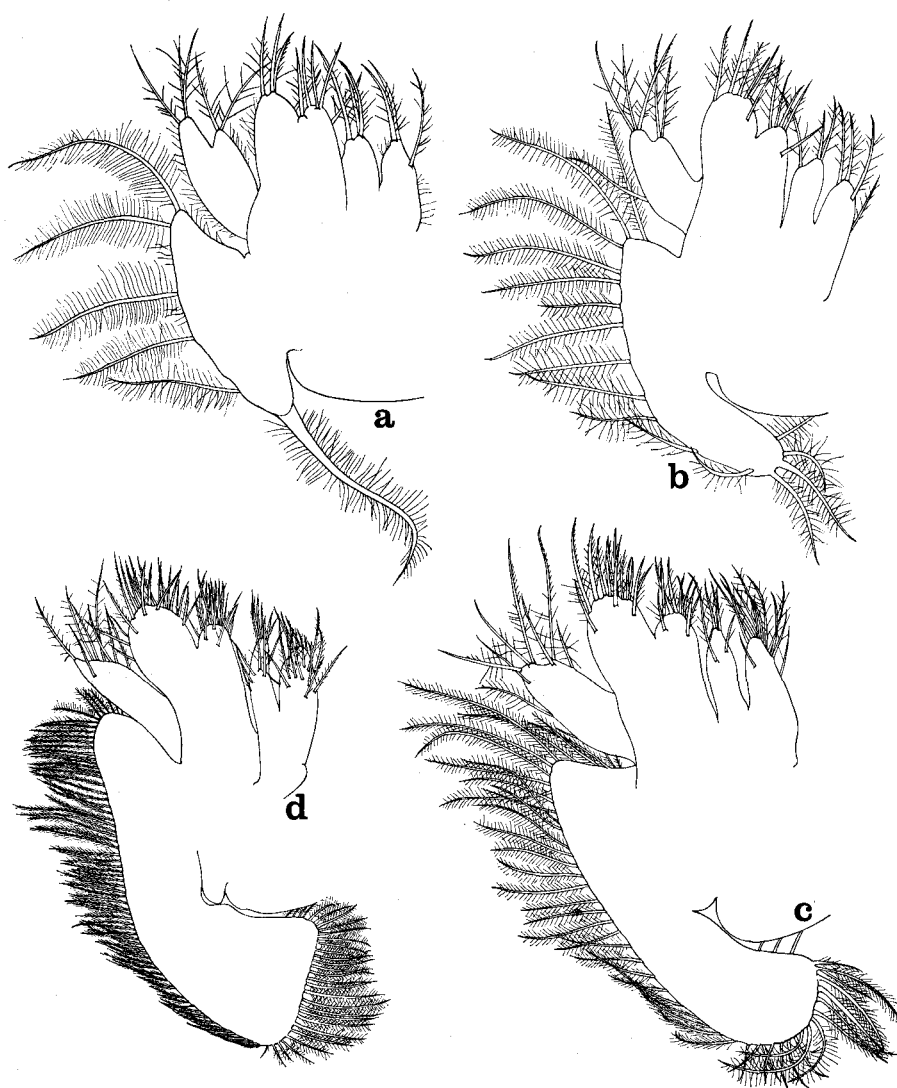


Fig. 9. Second maxillae of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage V zoea, d: in stage VIII zoea.

of the stage I-III zoeae. The proximal segment of the exopod bears four setae on the outer margin and the distal segment bears 20-23 natatory setae.

The first pereiopod is lengthened and bilobed near the tip incipiently to form the dactylus.

The branchial formula and ramification are as follows.



	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	-	-	-	-	1	1	1	-
Arthrobranchs	-	r	2	2	2	r+1	-	-
Podobranchs	1*	r	r	-	-	-	-	-
Endopods	1	1	1	1*	1	1	1	1
Exopods	1	1	-	-	-	-	-	-

(r = rudiment, \* = biramous)

In the second to fifth abdominal segments the ventrolateral spine is best with 1-2 small spines at the upper foot. The sixth abdominal segment bears two pairs of the dorsal spines.

Each arm of the telson (Fig. 14d) is broadened and bears on the posteromedial margin 9-10 strong setae and 4-7 slender ones.

The central part of the posteromedial margin furnished with these slender setae is remarkably engraved. The anterolateral spines are attenuated.

The exopod of the uropod (Fig. 16b) is now demarcated from the proximal segment and furnished with 15-16 plumose marginal setae. The endopod is defined on the inner margin as a bud.

#### Zoea V

The dorsal surface of the rostrum is slightly sulcate proximally along the median line, the carapace is provided with a marginal swelling just above each eye-stalk.

In the first antenna (Fig. 5e) the rod is furnished on the medial margin with four tiers of aesthetascs, respectively consisting of 5 : 5 : 4 : 2 ones from distal to proximal. The endopod or so-called ventral ramus appears as a small bud at the distal one-third of the rod.

In the second antenna (Fig. 6e) the endopod is further lengthened and about twice as long as the ventral serrated spine. The exopod is furnished with 36-37 plumose marginal setae.

In the mandible the palp appears as a small bud. The frontal edge of the incisor process is brimmed with a row of denticles which are roughly triangular and pointed at the tip.

In the first maxilla the proximal endite bears 17-19 marginal setae. The distal endite bears seven strong setae on the distal margin, 7-8 on the outer surface, 4-5 on the inner surface and 4-5 on the proximal margin. The palp bears 7-8 terminal setae, one seta on the inner and 1-2 setae on the outer margin.

In the second maxilla (Fig. 9c) the first to fourth endites are respectively furnished with 9-12 : 5-6 : 8-12 : 13-14 marginal setae. The palp bears 3-4, usually 3 setae on the terminal end, 3 on the inner and 3-4 on the outer margin. The scaphognathite

bears 52–56, rarely 50 marginal setae.

In the first maxilliped (Fig. 11b) the coxa bears 4–8 setae and the basis 30–32, rarely 26 setae. The ischium to the dactylus bear respectively 4–5, rarely 6 : 3 : 4, rarely 5 : 7, rarely 8 : 10–13 setae on the inner margin, and 0 : 0 : 3 : 3 : 4–5 setae on the outer margin. The proximal segment of the expood bears distally 5–6 setae and the distal segment bears 21–24 natatory setae.

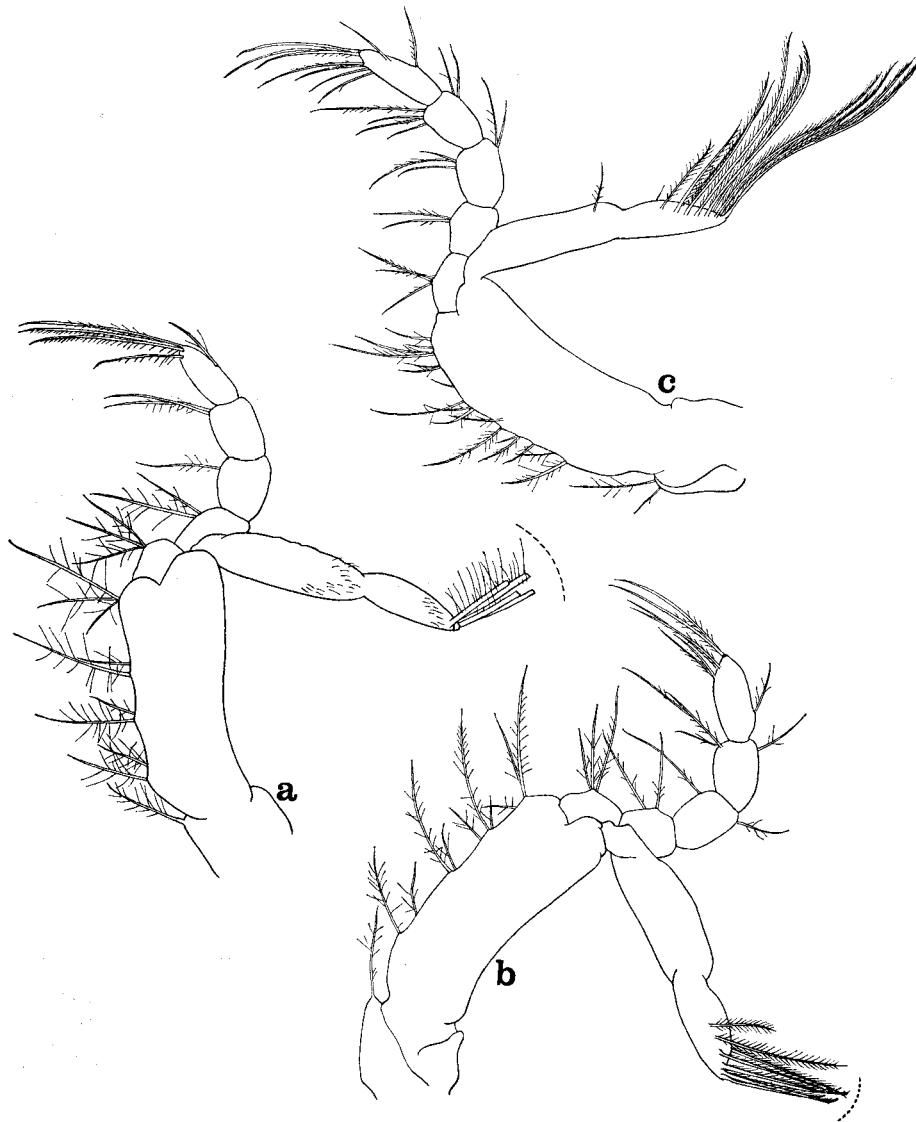


Fig. 10. First maxillipeds of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage III zoea.

In the second maxilliped (Fig. 12b) the coxa is armed with 3–4 setae. The setation in other segments remains unchanged or rather tends to be reduced in number. The proximal segment of the exopod bears 6–7 setae and the distal segment bears 25–27 natatory setae.

The first pereopod is chelate and indistinctly four-segmented. The second to fourth pereopods are indistinctly five-segmented each, and the fifth pereopod is obscurely two-segmented.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	–	–	–	–	1	1	1	–
Arthrobranchs	–	1	2	2	2	2	–	–
Podobranchs	1*	1*	1	–	–	–	–	–
Endopods	1	1	1	1*	1	1	1	1
Exopods	1	1	–	–	–	–	–	–

(r = rudiment, \* = biramous)

In the second to fifth abdominal segments the ventrolateral spines are enlarged, very pointed, and each with a few small spines on the roundly protruded upper foot, a rudimentary pleopod is defined on each side (Fig. 13c).

The posteromedial margin of the telson (Fig. 15a) is provided with 10–11 strong and 7–9 slender spines.

The exopod of the uropod is brimmed with 23–24 plumose setae.

## Zoea VI

On the carapace, the branchial regions are definable with distinctive sulcation. The lateral carapace spines (Fig. 4e) are shorter proportionally than in the preceding zoeal stages.

The first antenna (Fig. 5f) is armed with four tiers of usually five or often more aesthetascs and another more proximal tier of 2–4 aesthetascs. The rod is incompletely articulated about at the distal one-third, and just below it there is a ventral ramus demarcated from the rod.

In the second antenna (Fig. 7a) the ventral outer spine is slightly lengthened, but still shorter than the ventral serrated one. The endopod is further elongated and reaches about the middle of the exopod; it is slender in the distal half, but thick in the proximal half; the terminal seta is much diminished in length. The exopod is furnished with 40–43 plumose marginal setae.

The mandible has the palp simple and a little elongated.

In the first maxilla the proximal endite bears 21–25 marginal setae. The distal



Fig. 11. First maxillipeds of *Ranina ranina*, a: in stage IV zoea, b: in stage V zoea, c: in stage VI zoea.

endite bears 7–9 strong setae on the distal margin, 8–10 on the outer surface, 6 on the inner surface and 6 on the proximal margin. The palp bears 9–10 setae around the distal margin.

In the second maxilla the first to fourth endites bear respectively 9–13 : 5–8 : 10–12 : 12–18 marginal setae. The palp bears three plumose setae on the terminal and inner margins, and five on the outer margin. The scaphognathite is fringed with 66–75 marginal setae.

In the first maxilliped (Fig. 11c) the coxa and the basis bear respectively 9–11 : 34–36 setae on the inner margin. The ischium to the dactylus bear respectively 6–7 : 3–4 : 5–6 : 8 : 15 setae on the inner and 0 : 0 : 4 : 4–5 : 5–6 setae on the outer margin.

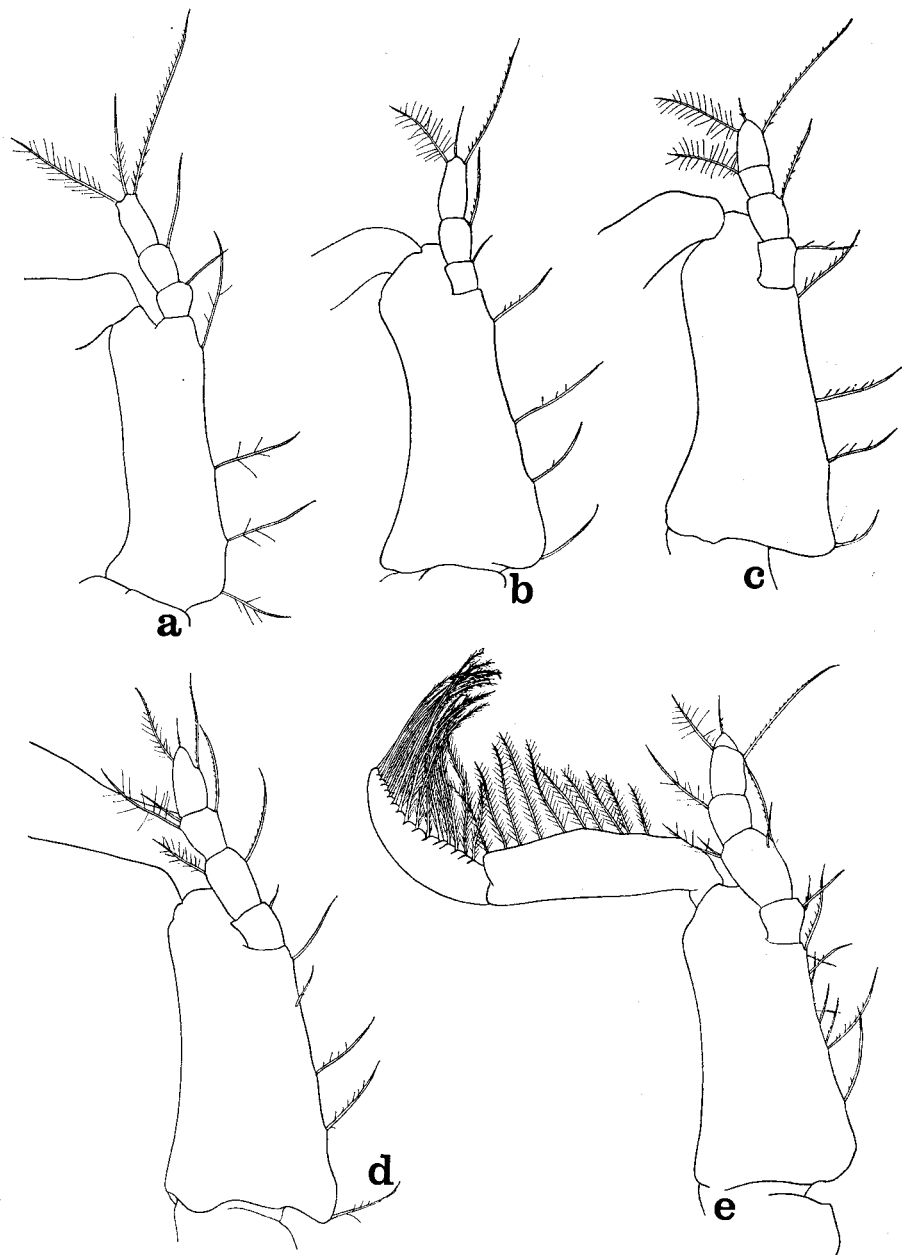


Fig. 12. Second maxillipeds of *Ranina ranina*, a: in stage I zoea, b: in stage V zoea, c: in stage VI zoea, d: in stage VII zoea, e: in stage VIII zoea.

The proximal segment of the exopod bears distally 8–9 setae, and the distal segment bears 24–26 natatory setae.

In the second maxilliped (Fig. 12c) the coxa and the basis bear respectively 2–5 : 5 setae. In the endopod the distal of the three segments is indistinctly articulated at its proximal one-third, and just below this suture there is a plumose seta on the outer margin. In the exopod the proximal segment bears nine setae, and the distal segment bears 27–32 natatory setae.

In the third maxilliped the exopod appears as a simple rod, and the endopod is two-segmented; there is an indication of suture to form a chela. The second to fifth pereopods are each four-segmented, and their distal segment is further articulated indistinctly.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	—	—	—	—	1	1	1	—
Arthrobranchs	—	1	2	2	2	2	—	—
Podobranchs	1*	1*	1	—	—	—	—	—
Endopods	1	1	1	1*	1	1	1	1
Exopods	1	1	—	—	—	—	—	—

(r = rudiment, \* = biramous)

The second to fifth abdominal pleopods are small, demarcated from respective abdominal segment, and each with an indication of the endopod.

The posteromedial margin of the telson (Fig. 15b) bears in each arm 9–12 strong and 8–9 slender spines.

The exopod of the uropod bears 28–33 plumose marginal setae.

## Zoea VII

The first antenna (Fig. 5g) is furnished with five tiers of five or more aesthetascs and another proximal tier of two or more aesthetascs. Two segments are differentiated distinctly in the rod; the peduncle and the dorsal ramus are completely articulated at the distal one-third of the rod; in the former the middle part is faintly narrowed by a slight concavity on the margin, which is noticed by two partial sutures on the dorsal side.

In the second antenna (Fig. 7b) the ventral outer spine is now slightly longer than the ventral serrated one. The endopod is incompletely three-segmented; the distal suture is positioned near the middle part and separates the slender distal segment from the thicker penultimate one which is then jointed with the proximal at the proximal suture situated a little below the distal one. The endopod reaches beyond the middle of the exopod bearing 47–49 plumose marginal setae.

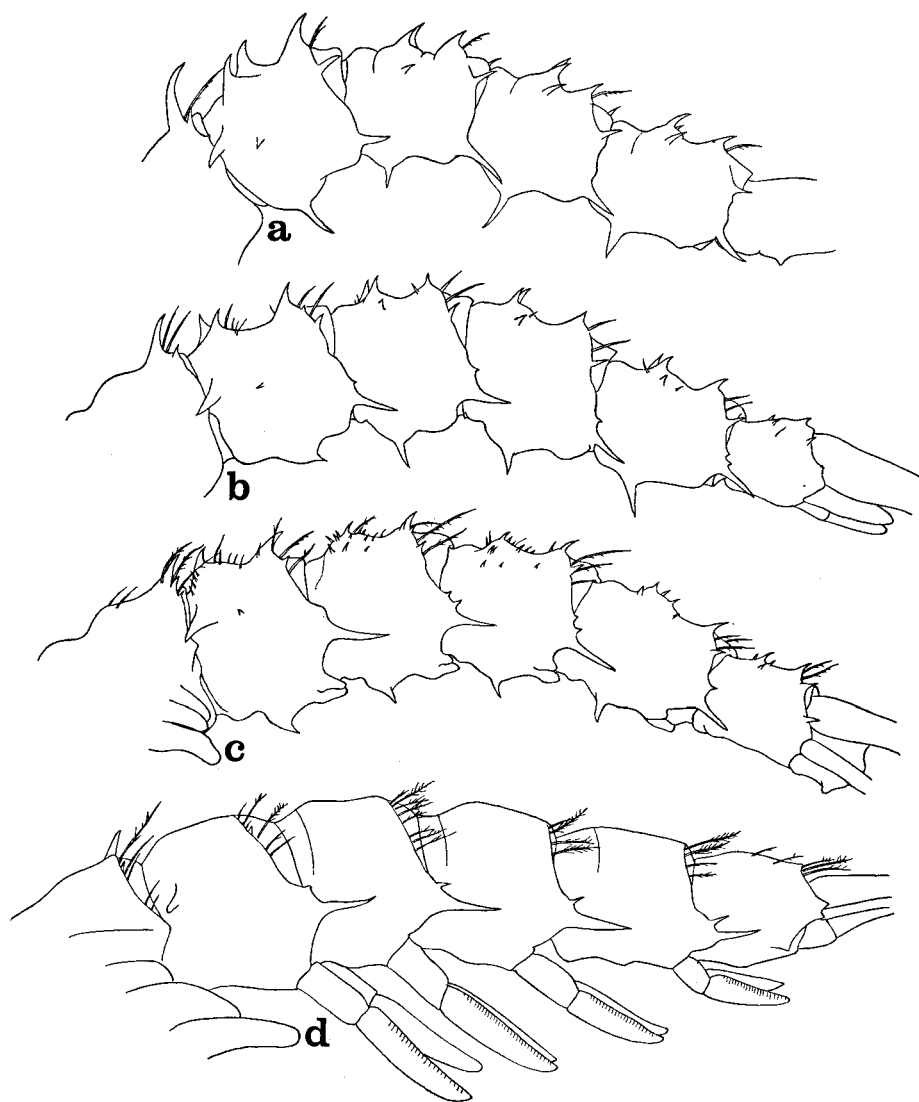


Fig. 13. Abdominal segments of *Ranina ranina* in lateral view, a: in stage I zoea, b: in stage III zoea, c: in stage V zoea, d: in stage VIII zoea.

In the mandible the palp is further elongated, two-segmented, and armed at the tip with two setae, long and short.

In the first maxilla the proximal endite bears 26–29 marginal setae. The distal endite is furnished with 8–10 strong marginal setae, 11–15 on the outer surface, 7–9 on the inner surface and 6–7 on the proximal margin. The palp bears 10–12 setae near the tip.

In the second maxilla the first to fourth endites are respectively provided with 15–16 : 7–10 : 11–16 : 16–19 marginal setae. The palp bears 6–9 sparse setae around the distal and inner margins, and 4–5 on the outer margin. The scaphognathite is fringed with 93–106 marginal setae.

The coxa and the basis bear respectively 10–13 : 39–42 setae.

The ischium to the dactylus are respectively furnished with 6–7 : 3–5 : 5–6 : 8–9 : 15–16 setae on the inner margin, and with 1 : 0 : 3–4 : 5–6 : 4–7 setae on the outer margin. In the exopod the proximal segment bears 8–10 setae and the distal segment bears 28–30 natatory setae.

In the second maxilliped (Fig. 12d) the coxa and the basis bear respectively 2–5 : 4–6 setae. The endopod is now four-segmented, the first or proximal segment bears often two setae on the inner margin, the second bears distally one seta on each of the inner and outer margins, and the third bears distally 1–2 setae on the inner and outer margins. In the exopod the proximal segment bears 9–10 setae and the distal segment bears 31–32 natatory setae.

In the third maxilliped the endopod is two-segmented, the proximal segment is further incompletely articulated. The first pereopod is completely chelate and consists of five segments including the dactylus. The second to fifth pereopods consist each of five segments.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	—	—	—	—	1	1	1	—
Arthrobranchs	—	1	2	2	2	2	—	—
Podobranchs	1*	1*	1	—	—	—	—	—
Endopods	1	1	1	1	1	1	1	1
Exopods	1	1	1	—	—	—	—	—

(\* = biramous)

The pleopods on the second to fifth abdominal segments are increased in size, the inner margin bears a rudimentary endopod at the proximal one-third.

The posteromedial margin of the telson bears in each arm 9–12 strong and 9–12 slender spines.

The exopod of the uropod bears 35–38 plumose marginal setae.

### Zoea VIII

The dorsal parts of the carapace separated by a longitudinal keel are fused with each other around the posterior part. The lateral carapace spines (Fig. 4f) are smaller proportionally than in the preceding zoeal stages and roughly triangular in shape.



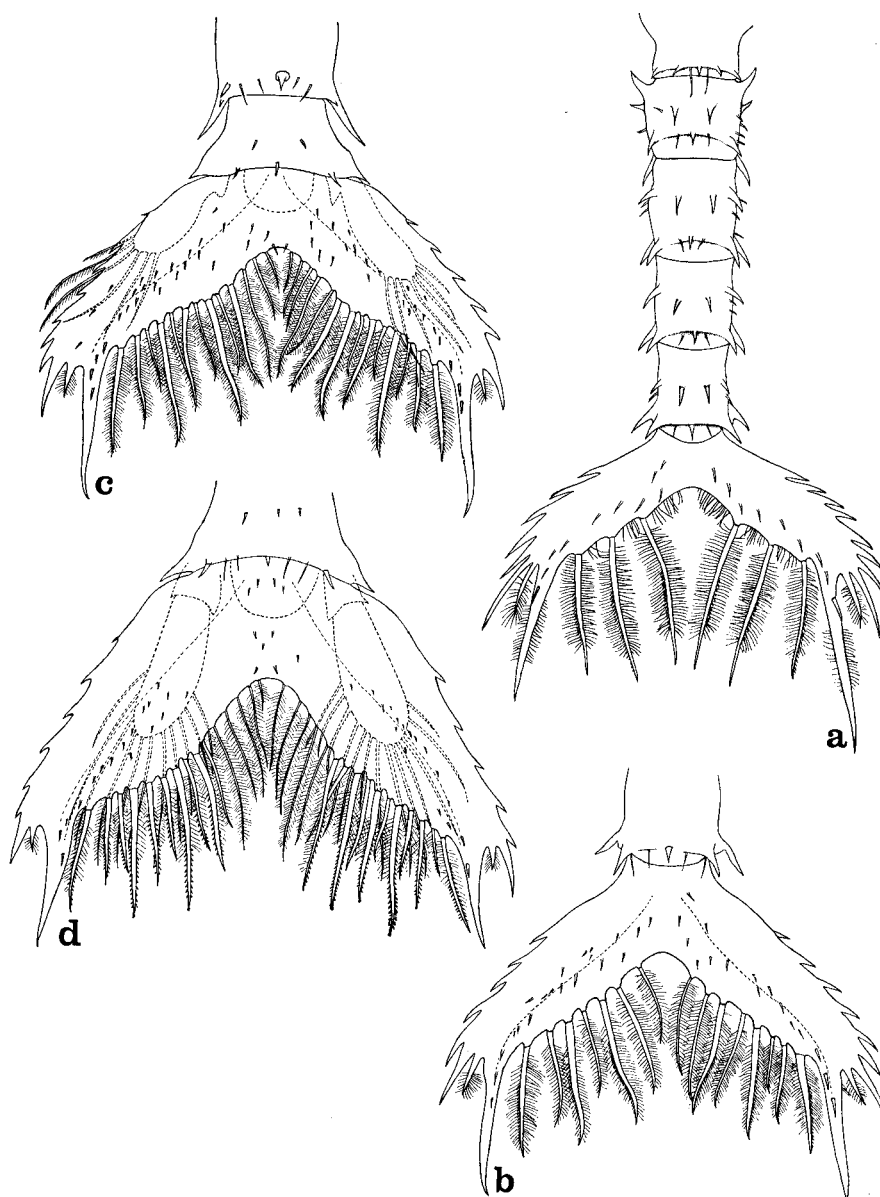


Fig. 14. Telsons of *Ranina ranina*, a: in stage I zoea, b: in stage II zoea, c: in stage III zoea, d: in stage IV zoea.

The first antenna (Fig. 5h) is provided with six or often seven tiers of aesthetascs on the medial margin, each tier bears more than five aesthetascs except the proximal one which is less furnished. The peduncle is incompletely three-segmented, as it is noted by partial articulations on the dorsal side seen at the proximal and distal levels

of the narrow middle part. The endopod is increased in length and bears sparsely a few setae.

In the second antenna (Fig. 8c) the endopod is further elongated, reaching almost the tip of the exopod, and with a short terminal seta. The ventral outer spine is distinctively longer than the ventral serrated one. The exopod is armed with 56-57 plumose marginal setae.

In the mandible (Fig. 8d) the palp is two-segmented, the distal segment showing an indication of articulation near the middle and with 2-3 terminal setae and a few

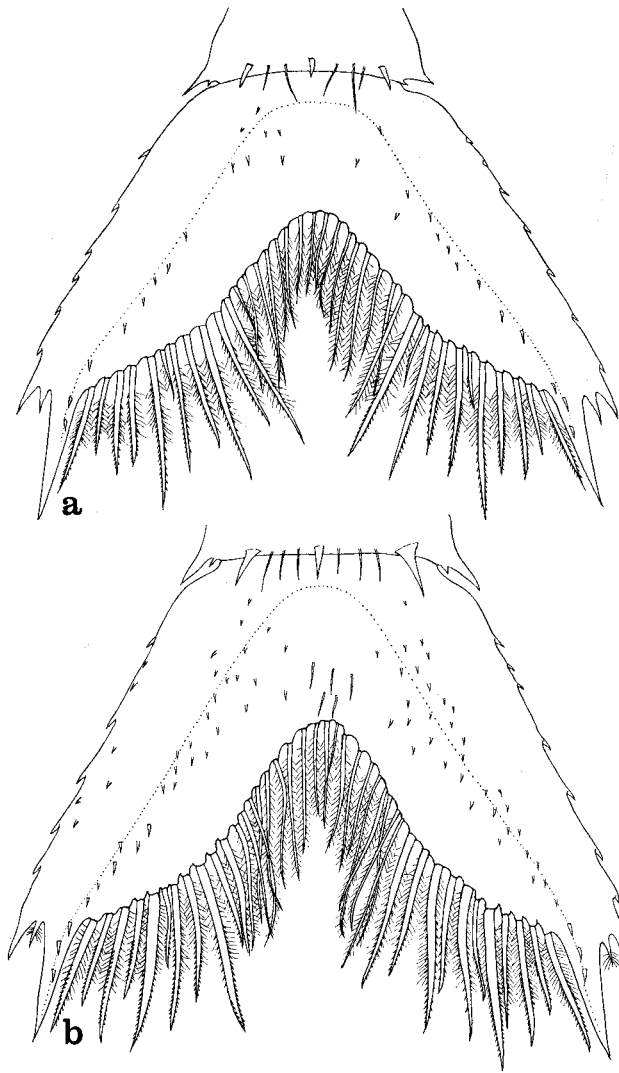


Fig. 15. Telsons of *Ranina ranina*, a: in stage V zoea, b: in stage VI zoea.

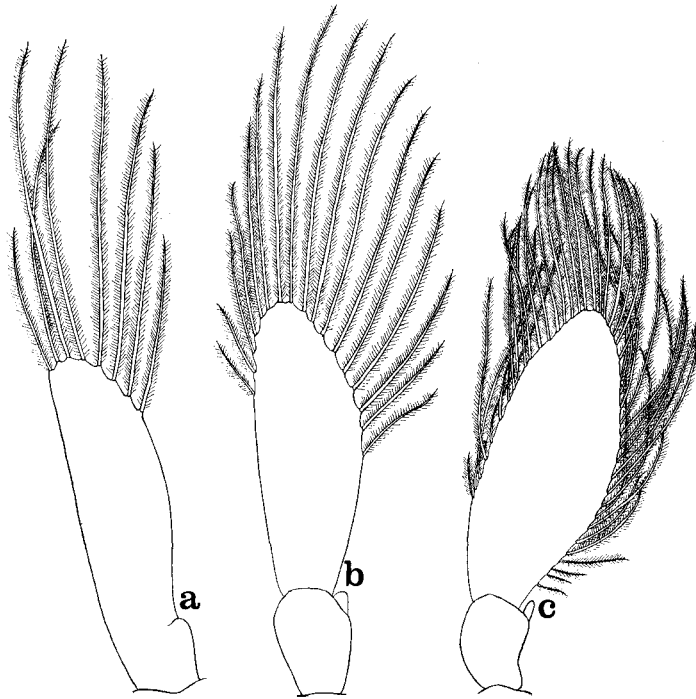


Fig. 16. Uropods of *Ranina ranina*, a: in stage III zoea, b: in stage IV zoea, c: in stage VIII zoea.

short indistinct ones on the medial margin.

In the first maxilla (Fig. 8c) the proximal endite bears 31–34 marginal setae. The distal endite bears 9–11 strong marginal setae, 15–20 on the outer surface, 8–9 on the inner surface and 8 on the proximal margin. The palp bears 12–14 setae.

In the second maxilla (Fig. 9d) the first, second, third and fourth endites are respectively furnished with 18–25 : 10–14 : 17–18 : 19–24 setae. The palp bears 7–9 setae around the distal and inner margins and 7–8 on the outer margin. The scaphognathite is fringed with 120–138 marginal setae.

In the first maxilliped the coxa and the basis bear respectively 15 : 18 setae on the inner margin. The ischium to the dactylus bear respectively 8 : 7 : 8 : 9 : 19 setae on the inner and 1 : 0 : 5 : 6 : 9 setae on the outer margin. In the exopod the proximal segment bears 12 setae and the distal segment bears 27 natatory setae.

In the second maxilliped (Fig. 12e) the coxa and the basis bear respectively 17 : 9–10 setae. The endopod consists of five segments; the distal segment is further divided into two segments. The penultimate segment of the endopod bears distally a seta on each of the inner and outer margins.

In the third maxilliped the endopod consists of five segments; the three distal

segments are each short, but the two proximal segments are long. The exopod is simple. The first to fifth pereopods are distinctly six-segmented.

The branchial formula and ramification are as follows.

	Maxillipeds			Pereiopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	—	—	—	—	1	1	M	—
Arthrobranchs	—	1	2	2	2M	2M	—	—
Podobranchs	1*	1*	M	—	—	—	—	—
Endopods	1	1	1	1*	1	1	1	1
Exopods	1	1	1	—	—	—	—	—

(\* = biramous, M = mastigobranch)

In the second to fifth abdominal segments (Fig. 13d) the exopod of the pleopod is demarcated from the basal segment, a small knob-like endopod is represented.

The posteromedial margin of the telson bears 9–12 strong and 10–13 slender spines.

The exopod of the uropod (Fig. 16c) bears 41–43 plumose marginal setae.

## V. Discussion

The larval carapace length of *Ranina ranina* affords a growth factor of 1.5 after the BROOK's law (BROOK, 1886) (Fig. 17). Although according to the GURNEY's notion (1942, pp. 81–83) this exponential series seems too high to be accepted, it may presumably be acceptable if the series of 1.56 obtained from the South African specimens of *Homola barbata* (RICE and VON LEVETZOW, 1967) is taken into consideration.

The first zoea of *R. ranina* from laboratory hatching was described by AIKAWA (1941) and RICE (1970). AIKAWA's larva has been often compared with other unknown zoeal larvae, but the result is not always complete.

There have been recorded eight uncertain larval forms related closely with the genus *Ranina*.

1. *Zoea gigas* WESTWOOD (1835), from the West Indies
2. Apteruriden sp. CLAUS (1876), from Bengal  
= *Acanthocaris* sp. CLAUS (1885)
3. *Lithozoea kagosimaensis* AIKAWA (1933), from the Korean strait
4. *Lithozoea multispinosa* AIKAWA (1933), from Kochi, Japan
5. *Acanthocaris* sp. GURNEY (1942), from Bermuda  
= Raninidae zoea A LEBOUR (1950)
6. Raninidae species B LEBOUR (1959), from the Atlantic Ocean
7. Raninidae zoea B LEBOUR (1950), from Bermuda
8. Raninidae species A LEBOUR (1959), from the Atlantic Ocean.

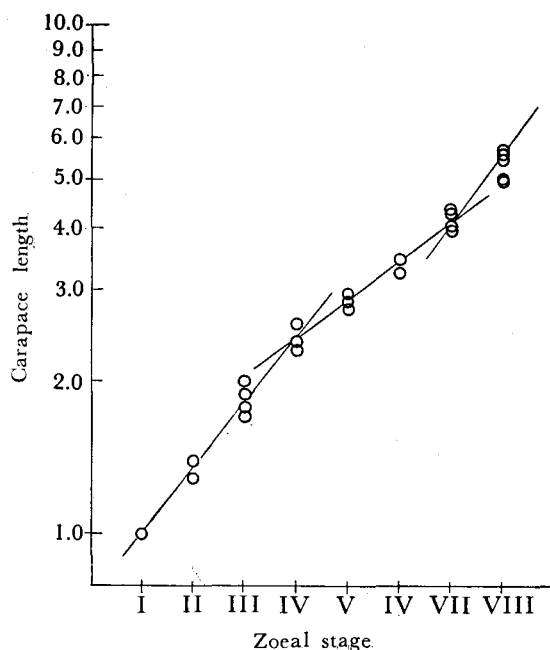


Fig. 17. Carapace lengths in successive larval stages of *Ranina ranina* reared in the laboratory, plotted logarithmically.

Among these forms Raninidae species B LEBOUR (1959) was regarded by LEBOUR (1959) herself as the same with Raninidae zoea A LEBOUR (1950) which is a larva of *Acanthocaris* sp. GURNEY (1942). WILLIAMSON (1965) expressed the view that CLAUS' larvae, *Apteruriden* sp. 1876 (= *Acanthocaris* sp. CLAUS, 1885), were distinguishable from those of *Ranina*, though GURNEY (1942) stated that CLAUS' larvae as well as WESTWOOD's one, *Zoea gigas*, were perhaps attributable to a Raninid. LEBOUR (1950) mentioned that the two larvae from Bermuda, Raninidae zoea A and B, were closely related to those of the genus *Ranina*.

In order to learn correctly the systematic situations of the above-mentioned larval forms, they are reviewed here on careful comparison with the zoeal series of *R. ranina* obtained from laboratory hatching. Firstly, those larvae may be divided into two sections, the forms from the Atlantic region and those from the Indo-Pacific region, according to their geographical distributions.

#### I. The larval forms from the Atlantic region.

Several larval forms have been reported from the Atlantic region, they are *Zoea gigas* WESTWOOD (1835), *Acanthocaris* sp. GURNEY (1942) (=Raninidae zoea A LEBOUR, 1950; Raninidae species B LEBOUR, 1959), Raninidae zoea B LEBOUR (1950), and Raninidae species A LEBOUR (1959).

1. *Zoea gigas* WESTWOOD

The morphology of *Zoea gigas* is given by WESTWOOD (1835) as it is 10 lines (about 22 mm) long between the points of the spines and provided with the palpigerous mandibles and the exopod on the third maxillipeds. The existence of the exopod is deduced from his description, "Immediately succeeding the outer pair of the natatory organs (=the second maxillipeds), . . . was discovered a pair of slender minute organs, composed of two joints, one long and one short, and furnished at the base with a still more minute lateral appendage (=the exopod) (p. 324).

Those characters of the WESTWOOD's larva do not accord with features of any zoeal stages of *R. ranina*. The former is applicable to the stage III-VIII zoeae of *R. ranina*: the palpigerous mandible to the stages V-VIII, the measurement between the points of the spines to the stage VI, and the existence of the exopod on the third maxilliped to the stages VII-VIII. The carapace length is about 4.7 mm on the figure given by WESTWOOD (Pl. IV, A), this may be applicable to the stage VII of *R. ranina*; the telson setation in his larva, probably with seven strong and six slender postero-medial setae (observed on his figure, though their exact appearances are unknown), may be applicable to the stage III-IV zoeae.

2. *Acanthocaris* sp. GURNEY (1942)

GURNEY's *Acanthocaris* from Bermuda is applicable to the stage I zoea of *R. ranina*, but the former is distinguished from the latter by the following points:

In *Acanthocaris* the exopod of the second antennae bears seven marginal setae and a ventral serrated spine proportionally much longer than that of *R. ranina*. In the first maxillae the outer margin of the distal endite has a single plumose seta, the proximal segment of the two-segmented palp bears a distinctive seta on the inner margin; in the second maxillae the first or proximal endite bears five setae, and the palp is provided with four setae on the distal lobe of the inner margin and with three setae on the proximal lobe; in the second maxillipeds the distal segment of the endopod bears six setae including a long inner seta.

On the contrary, in the stage I zoea of *R. ranina* the exopod of the second antennae bears six marginal setae. In the first maxillae the distal endite lacks a seta on the outer margin, and the proximal segment of the palp bears no long seta; in the second maxillae the first endite bears only three setae, the palp bears three setae on the distal lobe of the inner margin and two on the proximal. In the second maxillipeds the distal segment of the endopod bears only three setae.

As a result of such a comparison, GURNEY's *Acanthocaris* may probably be concluded to be nothing but a larva of the Atlantic species of the Raninidae.

## 3. Raninidae zoea A and B LEBOUR (1950)

LEBOUR (1950) described two Raninid larvae from Bermuda, Raninid zoea A (= *Acanthocaris* sp. GURNEY, 1942) and Raninid zoea B, and mentioned that they were related very closely to each other and probable belonging to the same genus with, or another genus nearly allied to *Ranina ranina*. Raninid zoea A is already examined

closely in the description of *Acanthocaris* sp. GURNEY, but a comparison between it and *R. ranina* is made now possible on the additional characters revealed here on the latter.

Raninid zoea A is brightly coloured; yellowish on the carapace and abdomen, with a bright red patch in the intestinal region and down the abdomen, while the larvae of *R. ranina* is not yellowish on the carapace, but colourless; only the rostrum and the dorsal carapace spine bear each characteristically one or more reddish stripes increasing in number with the stage.

Raninid zoea A bears a large spine projecting out from the front of the eye. Raninid zoea B has the second antenna with two very long terminal setae on the endopod but without the ventral spine; the telson forks are rounded (Fig. 6, E). Both Raninid zoea A and B bear a swelling on the carapace above the eye.

Zoeae of *R. ranina*, however, wholly differs from Raninid zoea A and B in that the swelling on the carapace and the armature on the eyes are both absent, the endopod of the second antenna bears a single plumose terminal seta and a ventral serrated spine, and the telson forks are rather slender.

#### 4. Raninidae species A and B LEBOUR (1959)

LEBOUR (1959) described two species of Raninid larvae from various stations of the Atlantic Ocean, Raninid species A and B. Raninid species B is ascribed to GURNEY's *Acanthocaris* or her Raninid zoea A, but Raninid species A seemingly represents a new form. LEBOUR mentioned that Raninid species A resembles closely some larva of *R. ranina*. It surely resembles the larval type of *R. ranina* in the shape of the lateral carapace spine, but differs from the latter in the telson armature. In Raninid species A the telson is provided with four short and three long setae on the posteromedial margin, however such a setation is not applicable to any zoeal stages of *R. ranina*.

## II. The larval forms from the Indo-Pacific region

Some uncertain larval forms which are evidently belonging to the Raninidae and closely related with larvae of *R. ranina* are reported from the Indo-Pacific region — larvae of the family Apteruriden CLAUS (1876) or of the genus *Acanthocaris* CLAUS (1885) and two larval species, *Lithozoea kagosimaensis* AIKAWA (1933) and *L. multi-spinosa* AIKAWA (1933), from Japan.

### 1. Larvae of the family Apteruriden CLAUS (1876)

Two zoeal larvae from Bengal were described by CLAUS (1876, 1885) under the name of the family Apteruriden (1876) or the genus *Acanthocaris* (1885) on the specimens respectively measuring 18 mm and 22–25 mm between the tips of the rostral and dorsal carapace spines.

The measurement of the smaller specimen is applicable to the stage IV zoea of *Ranina ranina* and that of the larger one to the stage VI zoea (Table 1). However, the features of the larger specimen, that the endopod of the second antenna reaches almost the tip of the exopod and the pleopods are well developed are applicable to the stage VIII zoea.

In the CLAUS' specimens (Pl. IX, fig. 13, 1876 and Pl. VII, fig. 53, 1885), the telson is rather slender and armed with a series of sharply pointed spines on the anterolateral and posterior margins, this feature is applicable to the stage I-III zoeae of *R. ranina*. The CLAUS' larvae bear twelve setae on the posteromedial margin of the telson, this is clearly less than in the later stage of *R. ranina*. In the form of the lateral carapace spines, WILLIAMSON (1965) has already pointed out that CLAUS' larvae are differentiated immediately from larvae of both *Ranina* and *Lyreidus*.

2. *Lithozoea kagosimaensis* and *L. multispinosa* AIKAWA (1933)

LEBOUR (1950) mentioned that her species, Raninid zoea A and B from Bermuda, are closely related with AIKAWA's species, especially *L. kagosimaensis* and *L. multispinosa*. The third species attributed to the genus *Lithozoea*, *L. serrulata* AIKAWA, 1933, is apparently different from the larvae of *R. ranina*.

*L. kagosimaensis* conforms to the stage II zoea of *R. ranina* in that the dactylus of the first maxilliped bears seven setae, the posteromedial margin of the telson is provided with six strong and two slender setae which are expressed by AIKAWA as "6 pairs of internal spines and 2 pairs of extra spines", and the carapace is 1.51 mm in length.

In spite of such similarities as mentioned above, AIKAWA's *L. kagosimaensis* differs from the stage II zoea of *R. ranina* in the following characters:

1. *L. kagosimaensis* has the rostrum, 3.90 mm long, which is shorter than the dorsal carapace spine 4.56 mm in length, on the contrary in *R. ranina* the rostrum is 5.0-5.6 mm and longer than the dorsal spine which is only 3.3-3.5 mm.

2. The dorsal carapace spine is 4.56 mm and the abdomen 2.16 mm, these are each much longer than in *R. ranina*. The dorsal carapace spine and the abdomen in *R. ranina* reach 3.3-3.5 mm and 1.7 mm respectively.

3. The endopod of the first maxilla is three-segmented according to AIKAWA, — this is very characteristic. In *R. ranina* it is two-segmented.

4. In the first and second maxillae the respective segments show a different setation between *L. kagosimaensis* and *R. ranina* zoea. Especially the scaphognathite bears 19 marginal setae in the AIKAWA's species but usually 16 in *R. ranina*,

5. In the first and second maxillipeds the exopod bears 14 natatory setae, while in *R. ranina* 10-11 and 11-13 setae respectively.

6. In AIKAWA's species the endopod of the second maxilliped bears 2 : 2 : 6 setae from the proximal segment to the distal, while in *R. ranina* it bears 1 : 1 : 3 setae.

The features of the second species, *L. multispinosa*, are applicable to the stage III zoea of *R. ranina* in the following points:

1. The carapace and the abdomen are respectively 1.98 and 2.34 mm in length, these are nearly the same as those in *R. ranina*, about 1.8 and 2.3 mm respectively.

2. The mandible, the first and second antennae, and the second maxilliped are built similarly in the two.



3. The exopod of the second antenna, the segments in the first and second maxillae, and the endopod of the second maxilliped (AIKAWA, 1933, Fig. 59-2) show the same setation in the two.

On the other hand, *L. multispinosa* is distinguishable from the stage III zoea of *R. ranina* by the following points.

1. The rostrum and the dorsal carapace spine are respectively 3.64 mm and 3.17 mm in length, these are much shorter than in *R. ranina*, as they are in the latter 7.1-8.0 mm and 5.0-5.3 mm respectively.

2. The endopod of the first maxilla is non-segmented and bears three setae on the tip and one a little below them in AIKAWA's species, while in *R. ranina* it is two-segmented and bears five setae on the tip and one subterminally on the inner margin.

3. In the first and second maxillipeds the exopod bears 14 natatory setae, but 16-18 ones in *R. ranina*.

4. The dactylus of the first maxilliped bears seven setae, but in *R. ranina* it bears 7-8 setae on the tip and two subterminally on the lateral margin.

5. The pleopods are already formed in AIKAWA's zoea, while they are missing in the stage III zoea of *R. ranina*; they will appear later in the stage V.

6. The posteromedial margin of the telson is provided with seven strong and 2-3 slender setae in AIKAWA's figure, these are less than in *R. ranina*, in which the setation is 8-9 strong and 3-5 slender in the stage III.

7. The exopod of the uropod bears eleven setae in AIKAWA's figure (1933, fig. 59-3), while it bears only eight in *R. ranina*.

WILLIAMSON (1970) recently described two larval forms of the Raninidae, NRS 40 and 41, from off the east coast of the Sinai Peninsula, the northern Red Sea, and mentioned that these species might belong respectively to *Ranilia dorsipes* (FABRICIUS) and *Cosmonotus grayii* ADAMS and WHITE.

NRS 40 is similar to the larvae of *R. ranina* in bearing a small lateral carapace spine on each side and a median ventral spine on abdominal segments II-V, but differs from the latter in bearing pleopods early in the stage III zoea, while in *R. ranina* pleopods appearing in the stage V zoea. The distance between the tips of the rostral and dorsal spines in the stage III zoea of NRS 40 is 12.5 mm, rather shorter than in *R. ranina*, in which the distance is 14.0-15.0 mm in the corresponding stage.

AIKAWA (1941) described the stage I zoea of *R. ranina* obtained from laboratory hatching. The larva shows a strong resemblance to the present specimens of the corresponding stage except for only some measurements — in AIKAWA's specimen the rostrum is 2.64 mm, the tip to tip of the rostral and dorsal spines 4.20 mm and the abdomen 1.98 mm, against this in the present specimens the rostrum 3.3-3.4 mm, the distance between the spines 6.6-7.3 mm and the abdomen 1.42-1.5 mm; the abdomen is proportionally shorter in the present specimens.

RICE (1970) has already pointed out that the distance between the tips of the

rostral and dorsal carapace spines is shorter in AIKAWA's Japanese specimen than in the specimens from Nouméa, New Caledonia, and this is proved to be true again for the present specimens.

Throughout the review made above, it may be safely concluded that CLAUS' Apteruriden (= *Acanthocaris*), *L. kagosimaensis*, *L. multispinosa*, NRS 40 and 41 are clearly distinguishable from the larvae of *R. ranina*.

As the development of larval features will never go on in parallel with one another between different species, the comparison and then the differences between those larval forms and the series of larvae of *R. ranina* can never be definitive to judge the exact stage of respective forms or to deduce the possible systematic position of the species to which respective larval forms belong to, though may be very helpful to do these.

## VI. Summary

The zoeal stages of *Ranina ranina* reared from berried females caught in Tosa-Bay, Japan are described. Eight zoeal stages were obtained in the laboratory. This is the third complete zoeal series reared in the laboratory known in the Raninidae.

Comparisons were made between the larvae of *R. ranina* and other unidentified zoeal larvae, *Zoea gigas* WESTWOOD (1835), Apteruriden sp. CLAUS (1876) (= *Acanthocaris* sp. CLAUS, 1885), *Acanthocaris* sp. GURNEY (1942) (= Raninidae zoea A LEBOUR, 1950, Raninidae species B LEBOUR, 1959), Raninidae zoea B LEBOUR (1950), and Raninidae species A LEBOUR (1959); it is concluded that all these larvae are completely different from the larvae of *R. ranina*.

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